

KING COUNTY CONVEYANCE SYSTEM IMPROVEMENT PROJECT

CONVEYANCE SYSTEM COST SYSTEM TRENCHLESS TECHNOLOGY COST PARAMETERS

FINAL REPORT

SEPTEMBER 2001



in association with

Brown and Caldwell

and

Herrara Environmental

INTRODUCTION

The purpose of this memo (originally written in 1999) is to define the parameters and unit costs used to the cost model for various trenchless technology alternatives. This memo includes specifics on the structure of the microtunneling, jacking and boring, and horizontal directional drilling (HDD) modules.

In most cases, gravity sewers and force mains will be constructed using open-trench construction techniques. However, open trench construction may not be viable when crossing environmentally sensitive areas, railroad right-of-way, creeks and streams, and major arterials. In these cases, trenchless technologies should or will need to be employed.

The trenchless construction techniques outlined in this memorandum are limited by pipe diameter, length of the bore, and geotechnical concerns. These construction constraints are discussed along with the applicability and cost estimating approach for each technology. Tunnels that would employ large diameter tunnel boring machines, such as tunnels 8-foot in diameter and greater, are covered in the tunnel cost parameters memorandum. A more general discussion of the cost system is included in the September 2001 *Conveyance System Cost Estimates – Task 250 Report*.

TRENCHLESS CONSTRUCTION COST MODEL

The model will be structured to provide the user with a formatted means of data entry and a formatted output for incorporation into other cost estimating models. The relationship between the scope of this work and other cost models is detailed in the Figure 1.

MICROTUNNEL COST MODULE

Microtunnel construction costs are influenced by a number of factors including the diameter of the microtunnel, soil conditions, length of the drive, and the depth of the launch and retrieval access shafts. These parameters and other factors were incorporated into this model component, providing user flexibility to adjust for site-specific conditions and design criteria that will likely be known at the planning level. All of the costs include contractor overhead and profit and are based on the cost estimates and bid prices for recent microtunneling projects.

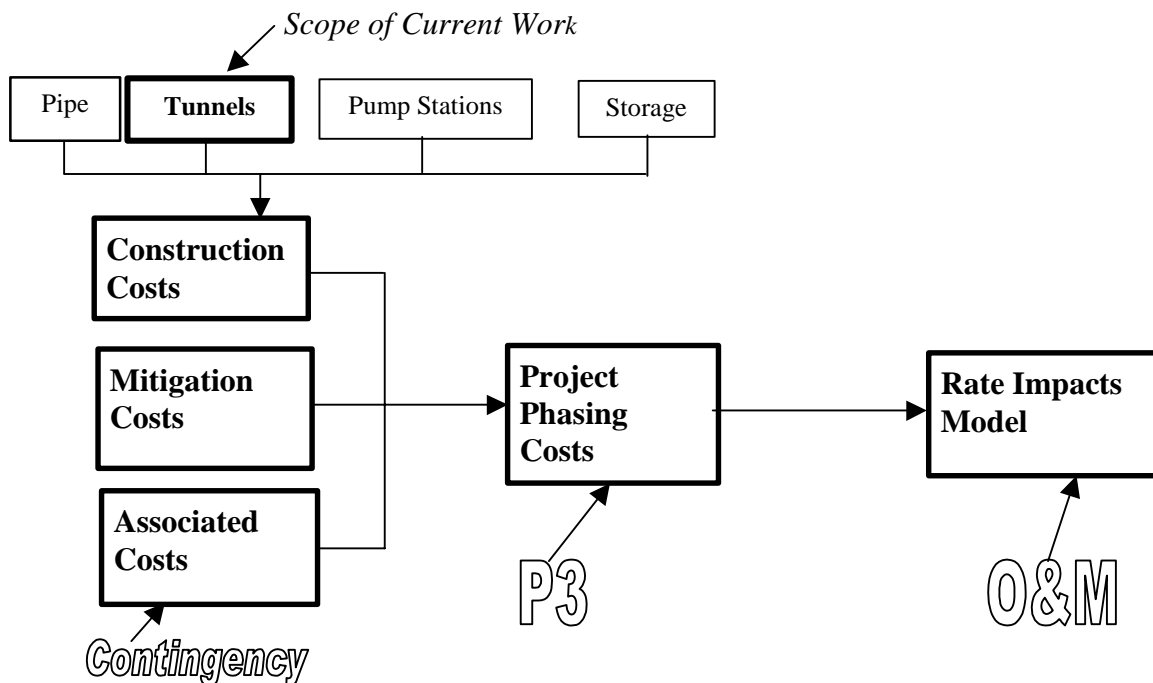


Figure 1. Cost Development Relationships

Microtunneling can only proceed in a relatively straight line from launch to retrieval shafts. With current technology, the maximum length between launch and retrieval shafts is typically about 1,000 feet. These length and alignment constraints require that intermediate shafts be excavated for longer microtunnels. In addition, this type of tunneling requires fairly homogenous soils types. The presence of cobbles and boulders makes control of the drill bit difficult and microtunneling is unadvisable in these soil conditions. A microtunnel through rock is difficult and is often cost prohibitive.

Fixed Model Parameters

Fixed parameters are imbedded in the model and are not modified by the user. These fixed parameters reflect unit prices for the base model month and year as shown on the introduction screen. Only the model caretaker can adjust them with password access. These parameter adjustments would typically only be done as part of modifying the model cost base month and year. Otherwise, these imbedded costs are not expected to vary significantly between projects. Table 1 lists those cost items with imbedded unit costs or percentage used in the initial model.

**Table 1. Fixed Input Parameters
December 1999 (ENR Seattle CCI = 7,137)**

Items	Units	Assumption/Unit Cost
Shaft Excavation, Backfill, and Haul	CY	\$25
Asphalt Pavement	SY	\$50
Existing Utilities (Average)	SF	\$6
Existing Utilities (Complex)	SF	\$10
Hydroseed	SY	\$5

A watertight shoring system was assumed for all of the launch and retrieval shafts. The cost for shoring increases with the depth of the shaft. This increase was assumed to be linear and is identified by the equation below.

$$\text{Cost (\$/sf)} = \$1.60 \times \text{Depth(ft)} + \$9$$

Based on this equation, the cost for shoring will increase with depth on a per square foot basis as outlined in Table 2.

Table 2. Shoring Costs

Shoring Depth (feet)	Unit Cost ¹ (\$/sf)
20	41
40	73
60	105
Notes: (¹) Costs based on ENR Seattle CCI = 7,137 for December 1999.	

User Input Parameters

The model is configured to allow for a variety of site conditions by adjusting certain input parameters. These project specific input parameters and the default values are summarized in Table 3. In some cases, there will be construction costs that are unique to a given project. These costs may include special landscaping requirements, artwork, unique street improvements, and other miscellaneous construction costs. To account for these costs at the planning stage, the user will be allowed to input a fixed dollar amount that will be calculated separately by the user. A comment box is included for noting the purpose of the additional costs.

Table 3. Project Specific Input Parameters

Parameter	Options	Default
Pipe Segment Name	User must input project name	Must be input by user
Construction Year	User may select future construction year	Current Year
Microtunnel Inside Diameter	12-84 inches	Must be input by user
Microtunnel Length	User must input	Must be input by user
Casing Required	Yes/No	No
Launch Shaft Utilities	None; Average; Complex	Average
Launch Shaft Excavation Depth	User must input number greater than 15 feet	40
Launch Shaft Surface Restoration	None; Hydroseed; Pavement	Hydroseed
Number of Intermediate Shafts	User must input	0
Average Intermediate Shaft Excavation Depth	User must input number greater than 15 feet	40
Average Intermediate Shaft Surface Restoration	None; Hydroseed; Pavement	Hydroseed
Retrieval Shaft Excavation Depth	User must input number greater than 10 feet	20
Retrieval Shaft Surface Restoration	None; Hydroseed; Pavement	Hydroseed
Unique Construction Costs	User must input description and total cost of item(s).	0
Dewatering	None; Standard; Significant	Standard
Traffic Control	None; Standard; Heavy	Standard
Total Length of Microtunnel Easements	User defined length	0
Type of Tunnel Easements	None; Residential; Industrial; Commercial	0

Casing Requirements

In some cases, a casing pipe will be required on microtunneling projects. For example, casing pipes will be required for force main undercrossings of railroad tracks, freeways, and major highways. Casing pipes may also be required for gravity sewer crossings of major transportation corridors. Other obstacles that may require casing pipes for microtunneled pipes are rivers, lakes, streams, and wetlands. In general, the casing pipe will be approximately 12-18 inches larger than the carrier pipe ID. Therefore, when casing pipes are required, the microtunneling cost will be based on the size of the casing pipe. The additional cost for the carrier pipe will be computed separately based on the pipe costs tabulated in the *Conveyance System Cost Systems Pipe Cost Parameters Report* prepared earlier and added into the output as a separate line item. For a more complete understanding of railroad crossing requirements, excerpts from the Burlington Northern and Santa Fe Railway (BNSF) are included in the Appendix A.

Microtunnel Characteristics

The microtunnel cost will vary based on the tunnel diameter and geotechnical conditions. There are significant costs for a microtunneling project associated with the procurement and delivery of the microtunnel boring machine (MTBM). These initial costs, combined with the costs for the launch and retrieval shafts will make shorter tunnels more expensive than longer tunnels when compared on a per-linear-foot of tunnel basis. For this reason, these mobilization costs are tabulated separately from the microtunneling costs (Table 4). These MTBM fixed costs are separate from the general project mobilization and demobilization costs.

Table 4. Microtunnel Dimensions and Costs

Microtunnel ID (in)	MTBM Fixed Costs ¹	Microtunnel Cost ¹ (\$/inch-diameter/lf)
12	\$90,000	\$30
15	\$100,000	\$28
18	\$120,000	\$27
21	\$140,000	\$26
24	\$160,000	\$26
30	\$200,000	\$25
36	\$250,000	\$24
42	\$300,000	\$23
48	\$350,000	\$22
54	\$400,000	\$22
60	\$450,000	\$21
66	\$500,000	\$20
72	\$550,000	\$19
84	\$600,000	\$18
Notes: (1) Costs based on ENR Seattle CCI = 7,137 for December 1999.		

Launch and Intermediate Shaft Characteristics

The costs of the launch and intermediate shafts will primarily vary with the footprint and depth of the shaft, and the amount of dewatering required for the site. Surface restoration requirements and other site-specific factors may also affect the launch shaft cost. The standard shaft footprint was developed based on a review of several microtunnel launch shafts. At a minimum, the shaft should be large enough to accommodate the MTBM, a 10-foot section of pipe, and the jacking mechanism. Based on a review of several launch and intermediate shafts, the standard shaft footprint is approximately 15 feet plus the pipe ID wide and 28 feet plus the pipe ID long. The unit costs identified in Table 1 will be used by the model to estimate the surface restoration and excavation costs for the shaft.

Retrieval Shaft Characteristics

Similar to the launch shaft, the cost of the retrieval shaft will primarily vary with the footprint and depth of the shaft and the need for dewatering. Surface restoration requirements and other site-specific factors may also significantly affect the retrieval shaft cost. In general, the retrieval shaft only needs to be large enough to accommodate the removal of the MTBM. Based on a review of retrieval shafts, the standard retrieval shaft footprint diameter is approximately 19 feet plus the pipe ID.

Right of Way

It is anticipated that tunnels will be constructed, to the maximum extent practical, in existing right-of-way. In some cases, tunneling easements and property acquisition may be required. The costs for easements and acquisitions were developed from previous County projects. These easement and acquisition costs are summarized in Table 5. To calculate the width of the tunneling easements, it was assumed that the permanent tunneling easement width would be equal to the microtunnel ID plus 20 feet. Another simple way to estimate the cost of property acquisition and microtunneling easements at the planning stage would be to download or otherwise acquire the parcel information for the parcels transected by the proposed microtunnel alignment from the office of the King County Assessor. If this parcel specific approach is used, the user should enter “0” for the length of tunnel easements and enter the estimated value of the easements in the “Unique Construction Costs” box.

Table 5. Right-of-Way Acquisition and Easement Costs

Area	Property Acquisition Cost¹ (\$/sf)	Tunneling Easements^{1,2} (\$/sf)
Residential	\$22	\$7
Industrial	\$10	\$3
Office/Commercial	\$20	\$6
Notes: (1) Costs based on ENR Seattle CCI = 7,137 for December 1999. (2) Acquisition and easement costs are based on a King County memo from William Wilbert to Ed Cox RE: Value Estimates for Property Types.		

Dewatering

In most cases, dewatering will be minimal since watertight shoring systems will be used at both the launch and retrieval shafts. Nonetheless, some dewatering will be required. Table 6 summarizes these dewatering costs for a given length project. In reality, the dewatering cost will include some initial costs plus additional costs to maintain the system for the duration that the launch and retrieval shafts are open. The microtunnel length was used as a surrogate

to estimate the duration that the dewatering systems will need to function at an estimated cost of \$350 per day.

Table 6. Dewatering Costs

Number of Shafts	Standard Dewatering¹ (Total \$)	Significant Dewatering¹ (Total \$)
2	\$40,000	\$60,000
3	\$45,000	\$70,000
4	\$50,000	\$90,000
5	\$60,000	\$100,000
>5	\$75,000	\$120,000
Notes: (1) Costs based on ENR Seattle CCI = 7,137 for December 1999.		

Traffic Control

Oftentimes, no traffic control will be required since the microtunnel access shafts will be located in parks, parking lots, or other areas where there is no vehicular traffic. However, in some cases, the microtunnel access shafts will need to be located in roadways and traffic control will be required. These traffic control costs are summarized in Table 7.

Table 7. Traffic Control Costs Per Shaft

Standard¹ (Total \$)	Heavy Traffic¹ (Total \$)
\$15,000	\$25,000
Notes: (1) Costs based on ENR Seattle CCI = 7,137 for December 1999.	

Outputs

The output from the model will summarize the input parameters and model outputs in a spreadsheet format that can be exported into other King County cost model components.

JACK AND BORE COST MODULE

Jack and bore construction is similar to that for microtunneling in that construction requires jacking and receiving pits with a pipe jacked in between the two. The primary difference is

that a jack and bore uses an open faced cutter head while MTBMs are typically closed face. Jack and bore construction is typically limited to lengths of less than 250 feet and for areas above the groundwater table since the bore will typically involve open face construction. This constraint usually limits the depth of the launch and retrieval shafts, which are typically slightly smaller than those for an equivalent microtunnel project. As with microtunneling, jacking and boring requires fairly homogenous soils types and areas with a possibility of large cobbles and boulders is unadvisable. Even under the best conditions, jacking and boring through rock is difficult and often cost-prohibitive. However, where conditions permit, a jack and bore construction is typically less expensive than an equivalent microtunnel project.

Cost Model Elements

In many ways, the jack and bore cost model elements will be identical to those for the microtunnel cost module. These identical cost elements include:

- Fixed model parameters,
- Casing requirements, and
- Right-of-way acquisition.

The shaft size will be slightly reduced as will the dewatering requirements since a jack and bore should take place well above the groundwater table. A modest dewatering cost of \$7,000 is allowed.

User Input Parameters

The model is configured to allow for a variety of site conditions by adjusting certain input parameters. These project specific input parameters and the default values are summarized in Table 8. In some cases, there will be construction costs that are unique to a given project. These costs may include special landscaping requirements, artwork, unique street improvements, and other miscellaneous construction costs. To account for these costs at the planning stage, the user will be allowed to input a fixed dollar amount that will be calculated separately by the user with a box for noting what the additional costs include.

Table 8. Project Specific Input Parameters

Parameter	Options	Default
Pipe Segment Name	User must input project name	Must be input by user
Construction Year	User may select future construction year	Current Year
Bore Inside Diameter	12-84 inches	Must be input by user
Bore Length	User must input	Must be input by user
Casing Required	Yes/No	No
Dewatering for Shafts	None; Standard	None
Launch Shaft Utilities	None; Average Complex	Average
Launch Shaft Excavation Depth	User must input number greater than 15 feet	40
Launch Shaft Surface Restoration	None; Hydroseed; Pavement	Hydroseed
Retrieval Shaft Excavation Depth	User must input number greater than 10 feet	20
Retrieval Shaft Surface Restoration	None; Hydroseed, Pavement	Hydroseed
Unique Construction Costs	User must input a cost number	0
Total Length of Easements	User defined length	0
Type of Easements	None; Residential; Industrial; Commercial	0

Launch Characteristics

The cost of the launch shaft will primarily vary with the shaft footprint and depth. Surface restoration requirements and other site-specific factors may also affect the launch shaft cost. The standard launch shaft footprint is approximately 13 feet plus the pipe ID wide and with a length of 24 feet plus the pipe ID. The unit costs identified in Table 1 will be used by the model to estimate the surface restoration and excavation costs for the launch shaft.

Bore Characteristics

The jack and bore cost will vary primarily based upon the bore diameter. These costs are summarized in Table 9. Although there will be some mobilization and demobilization costs associated with the jack and bore, they are expected to be significantly less than the costs associated with the procurement and mobilization for a microtunnel and are expected to be covered in the 10% mobilization and demobilization costs associated with the project.

Table 9. Bore Dimensions and Costs

Bore ID (in)	Bore Cost¹ (\$/inch-diameter/lf)
12	\$27
15	\$25
18	\$24
21	\$23
24	\$23
30	\$22
36	\$21
42	\$20
48	\$20
54	\$20
60	\$19
66	\$19
72	\$18
84	\$18
90	\$17
96	\$17
108	\$16
120	\$16
Notes: ⁽¹⁾ Costs based on ENR Seattle CCI = 7,137 for December 1999.	

Retrieval Shaft Characteristics

Similar to the launch shaft, the cost of the retrieval shaft will primarily vary with the footprint and depth. Surface restoration requirements and other site-specific factors may also significantly affect the retrieval shaft cost. For some pipes less than 36 inches in diameter, a large manhole can be used. The unit costs identified in Table 1 will be used to estimate the cost for the retrieval shaft. The standard retrieval shaft footprint is 13 feet plus the pipe ID wide and with a length of 19 feet plus the pipe ID.

Outputs

The output from the model will summarize the input parameters and model outputs in a spreadsheet format that can be exported into other King County cost model components.

HORIZONTAL DIRECTIONAL DRILLING MODULE

Horizontal directional drilling (HDD) is frequently used for watermains, force mains, and other pressurized pipes. Since the alignment and grade tolerances for HDD are less than those for microtunneling or jacked and bored crossings, it is typically not recommended for gravity sewer pipes. HDD has been used to install pipes up to 48-inches in diameter and up to 6,000 feet long. In general, it is recommended that there be a minimum of 20 feet of cover beneath freeways, structures, and rivers for HDD installed pipes. More information on this construction technique is included in Appendix B.

Cost Model Elements

HDD projects consist of a HDD section of pipe with a “drill-rig side” work area and a “pipe side” work area. A typical HDD project starts with the drilling of the pilot hole from the rig side to the pipe side. A reamer is then attached to the pilot string and the hole is enlarged to accommodate the pipe to be installed. Then the pipe, preferably assembled into one long string prior to pullback, is pulled into the hole. The primary cost elements for a HDD project are the pipe size and length. Secondary cost elements include work space constraints, especially constraints that prohibit fusing together of a continuous pipe string prior to pullback and geotechnical concerns. These elements are discussed in more detail below.

Surface Restoration

For this module it is assumed that the surface restoration will be limited to the slurry pits. The standard launch shaft footprint is approximately 13 feet plus the pipe ID wide and with a length of 24 feet plus the pipe ID. The unit costs identified in Table 1 will be used by the model to estimate the surface restoration and excavation costs for the launch shaft.

User Input Parameters

The model is configured to allow for a variety of site conditions by adjusting certain input parameters. These project specific input parameters and the default values are summarized in Table 10. In some cases, there will be construction costs that are unique to a given project. These costs may include special landscaping requirements, artwork, unique street improvements, and other miscellaneous construction costs. To account for these costs at the planning stage, the user will be allowed to input a fixed dollar amount that will be calculated separately by the user with a box for noting what the additional costs include.

Table 10. Project Specific Input Parameters

Parameter	Options	Default
Pipe Segment Name	User must input project name	Must be input by user
Construction Year	User may select future construction year	Current Year
HDD Pipe ID	8-48 inches	Must be input by user
HDD Length	User must input	Must be input by user
Casing Required	Yes/No	No
Rig Side Utilities	None; Average Complex	Average
Rig Side Surface Restoration	None; Hydroseed; Pavement	Hydroseed
Pipe Side Utilities	None; Average Complex	Average
Pipe Side Surface Restoration	None; Hydroseed, Pavement	Hydroseed
Gravels and Cobbles Present	Yes/No	No
Constrained Rig Side Space	Yes/No	No
Constrained Pipe Side Space	Yes/No	No
Unique Construction Costs	User must input a cost number	0
Total Length of Easements	User defined length	0
Type of Easements	None; Residential; Industrial; Commercial	0

HDD Costs

The HDD cost will vary primarily based upon the bore diameter. These costs are summarized in Table 11. Although there will be some mobilization and demobilization costs associated with the HDD, they are expected to be significantly less than the costs associated with the procurement and mobilization for a microtunnel and are expected to be covered in the 10% mobilization and demobilization costs associated with the project.

Table 11. HDD Dimensions and Costs

HDD ID (in)	HDD Cost ¹ (\$/lf)
6	\$50
12	\$150
15	\$260
18	\$320
21	\$400
24	\$450
30	\$540
36	\$640
42	\$760
48	\$860
Notes: ⁽¹⁾ Costs based on ENR Seattle CCI = 7,137 for December 1999.	

HDD is best suited for fine cohesive soils such as clays, silts, and fine sands since it is much easier to drill through these soils and maintain an open hole for pull back than through less cohesive soils such as sands and gravels. However, HDD projects have been successfully completed through less cohesive soils, including soils with cobbles. To account for the additional difficulty of drilling through these soils, it is recommended that the following additional costs be included as applicable:

- Gravels and Cobbles: Additional 20 percent,
- Constrained Rig Side Space (less than 30 feet by 100 feet): Additional 10 percent, and
- Constrained Pipe Side Space (insufficient to lay out entire pipe string): Additional 15 percent.

Outputs

The output from the model will summarize the input parameters and model outputs in a spreadsheet format that can be exported into other King County cost model components.

APPENDIX A
BNSF UTILITY CROSSING GUIDELINES

APPENDIX B
GUIDELINES FOR A SUCCESSFUL
DIRECTIONAL CROSSING BID PACKAGE